

INTELLIGENT PAPER™ QUESTIONNAIRE

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ABSTRACT

THE VOTATION INTELLIGENT PAPER™ QUESTIONNAIRE IS A PAPER QUESTIONNAIRE WITH MICROELECTRONIC COMPONENTS EMBEDDED OR ATTACHED. QUESTIONS ARE PRESENTED TO THE RESPONDENT EITHER PRINTED ON THE PAPER OR VIEWED ON A LIQUID CRYSTAL DISPLAY ATTACHED TO THE PAPER. RESPONDENTS REPLY BY EITHER CHECKING A BOX, PRINTED OVER AN EMBEDDED SWITCH, OR THROUGH THE USE OF AN ALPHANUMERIC KEYBOARD INCORPORATED WITHIN THE PAPER. INSTRUCTIONS AND ANSWERS ARE STORED IN EMBEDDED MEMORY. THUS THE IPQ IS A FULLY FUNCTIONAL, SINGLE USE, DISPOSABLE ELECTRONIC DATA COLLECTION DEVICE. THIS PAPER DESCRIBES THIS MARRIAGE OF PAPER AND ELECTRONICS AND HYPOTHESIZES ON THE POTENTIAL RAMIFICATIONS THAT "INTELLIGENT PAPER" CAN HAVE ON THE SURVEY AND CENSUS ENVIRONMENT. "INTELLIGENT PAPER" IS A PATENT PENDING PRODUCT OF VOTATION CORPORATION AS FILED BOTH IN THE UNITED STATES AND INTERNATIONALLY.

KEYWORDS

COMPUTER ASSISTED SURVEY INFORMATION COLLECTION (CASIC), COMPUTER ASSISTED PERSONAL INTERVIEW (CAPI), COMPUTER ASSISTED SELF INTERVIEWING (CASI), COMPUTER ASSISTED INTERVIEWING (CAI), COMPUTER-AIDED SURVEY EXECUTING SYSTEM (CASES), ELECTRONIC QUESTIONNAIRES, CENSUS, PAPER DATA COLLECTION, ELECTRONIC DATA COLLECTION, MICROCONTROLLER APPLICATIONS, SINGLE USE ELECTRONIC DEVICES, DATA INPUT DEVICES, REMOTE DATA COLLECTION DEVICES, INTELLIGENT PAPER™, TAX FORMS, ELECTRONIC FILING.

THE INTELLIGENT PAPER™

Over the past several years technological improvements have dramatically changed how statistical organizations collect, capture, and process respondent data. There is one very significant area of survey or census work that has not found a cost effective technology that would let it make the significant improvements in data collection and capture experienced by other types of censuses or surveys. Large volume, respondent completed, multi-page demographic or household surveys or censuses have tried, but generally found: 1) Computer Assisted Telephone Interviewing (CATI) is too expensive, 2) touchtone telephones have problems with alphabets, 3) home computer and faxes are not readily available, 4) voice recognition is not accurate enough, and 5) scanning has promise, but the equipment is expensive and handwriting recognition has problems. The result is that these types of large scale data collection efforts must still rely on paper as the collection medium and a pencil as the data input device. This paper will describe a new technology that we believe will fill this void.

Votation's Intelligent Paper™ evolved from a research program conducted to improve the process by which data is collected on paper, captured, and then moved into the data processing system. (The Intelligent Paper™ Product is the subject of one or more patents filed in the U.S. and Internationally under the Patent Cooperation Treaty (PCT) by Votation Corporation.) The goals of the project were to identify methods that would reduce the cost, reduce the data processing infrastructure required, and improve the process of large scale data collection. At the outset of the project, it was determined that an electronic solution would be necessary to achieve these goals. The project results determined that making paper "intelligent", through the integration of low cost, single use microelectronics, was a viable solution and would facilitate a design to meet program goals.

Figure 1, Intelligent Paper™ Questionnaire, shows the resulting Intelligent Paper™ design and the specific functional elements related to the Intelligent Paper's™ use as a general purpose data collection device. The Intelligent Paper™ is a fully functional electronic device consisting of three layers of paper in which each layer provides a specific function related to the integration of the electronics and its associated circuits.

The Intelligent Paper™ design incorporates many recent technology advancements in microelectronic components such as application specific integrated circuits (ASICs) and other devices that allow for a low cost, electronic data collection solution. Other advances incorporated include a method of attaching microelectronic components to printed electronic circuits by gluing the micro chip to a circuit with electrically conductive adhesive. These and other technology advances, along with the Votation R & D teams' focused research to improve the data collection process, resulted in the development of Intelligent Paper™ and the Intelligent Paper™ Questionnaire (IPQ).

In the general purpose configuration shown in Figure 1, the Intelligent Paper™ Questionnaire, has a paper face with an integrated alphanumeric keyboard for data entry, a flexible plastic liquid crystal display for question presentation and user feedback, and software controllable softswitches.

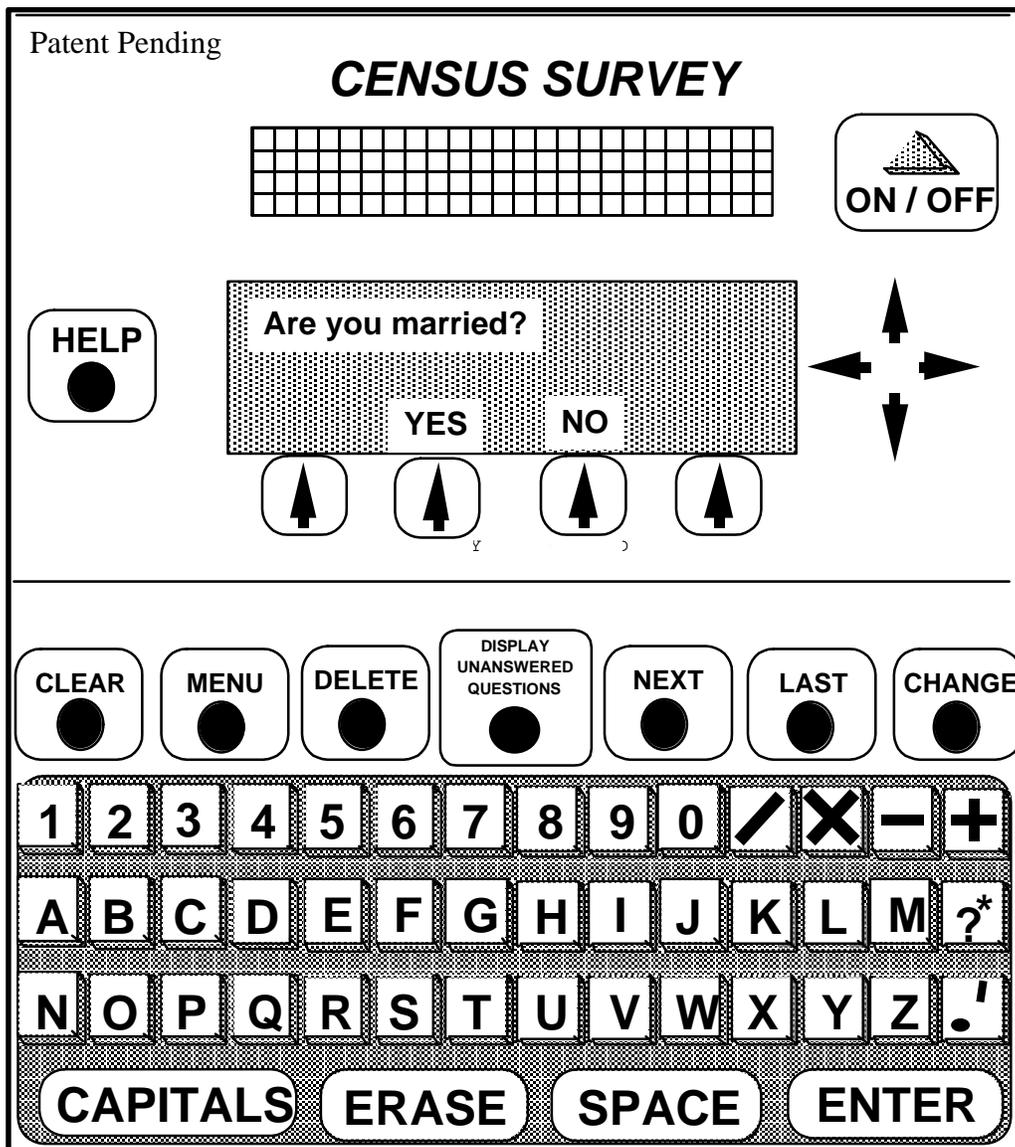


Figure 1 • Intelligent Paper Questionnaire

The keyboard and other features of the Intelligent Paper's™ top or face, so called "topology" element, are designed for ease of use by the respondent. Topology elements can be changed to meet specific data collection requirements. Figure 2, Intelligent Paper™ Questionnaire Construction, shows how the IPQ is assembled. It consists of the top face, a middle paper layer and a back paper layer. The back layer contains a microelectronic processor (microcontroller) and connective circuits. It also contains half of the switch circuit. The function of the middle layer is to provide for isolation and insulation of the circuitry on the bottom layer. The back of the top layer contains the other half of the switch circuitry. The switches operate by depressing the key on the top layer and moving the top switch half through a hole in the middle layer to contact the back layer switch half. This key depression is detected by the Intelligent Paper™ microcontroller which then performs the specified processing action. When pressure is removed from the switch, the natural tension of the top layer paper retracts and breaks the contact; therefore, providing the momentary contact desired.

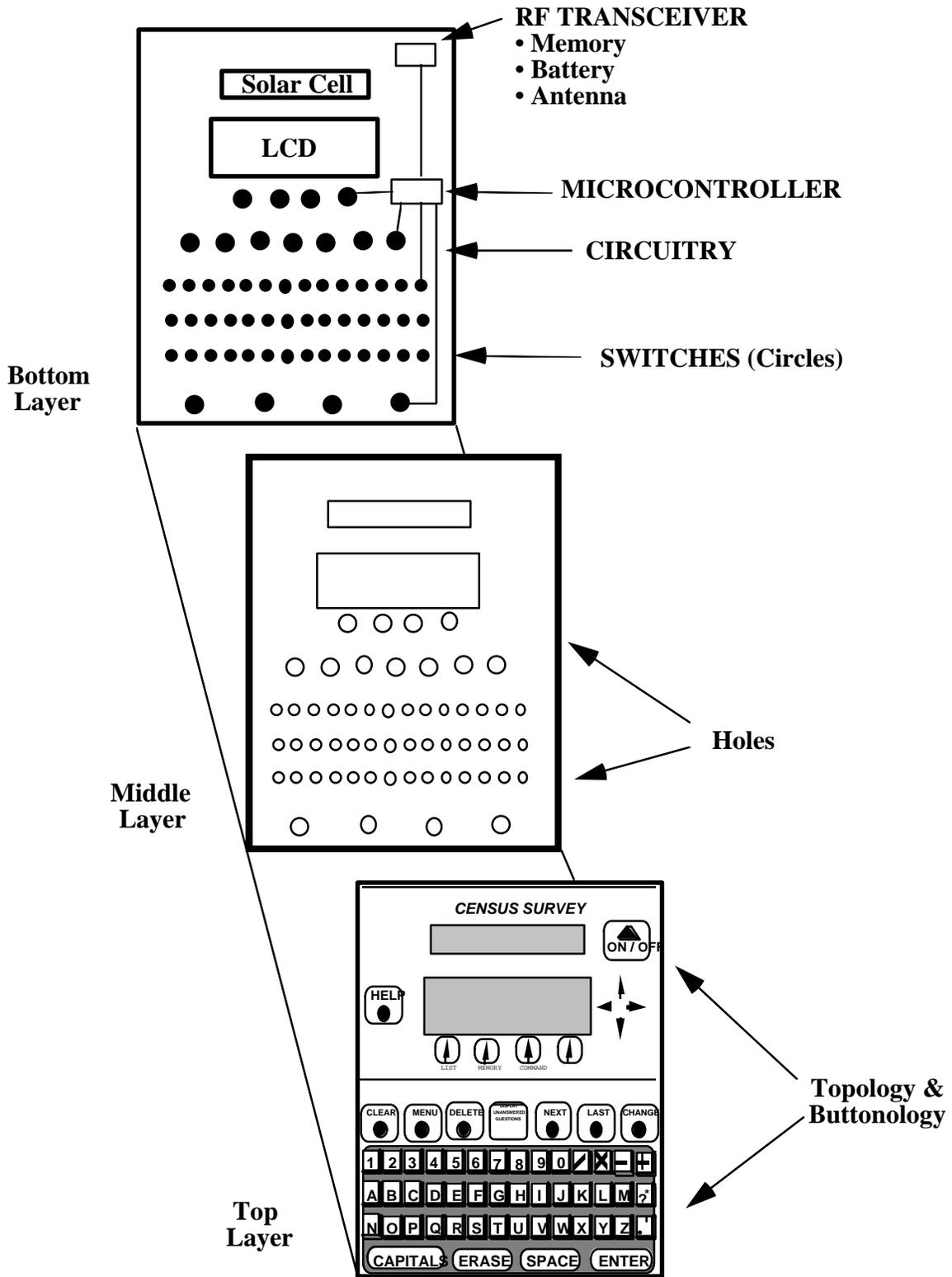


Figure 2 • Intelligent Paper™ Questionnaire Construction

The microcontroller provides all functions required to make the Intelligent Paper™ a complete data collection tool. Its memory stores the questions that will be displayed to the respondent on the LCD. The microcontroller and its memory receives and stores the collected data and facilitates data transfer from the Intelligent Paper™ to the data processing system through an integrated two way digital radio frequency transceiver. Figure 3, Intelligent Paper™ to Data Processing System RF Interface, shows the equipment and conditions for transmitting the data from the device into the external data processing system.

Incorporation of the radio transceiver in Intelligent Paper™ is a major feature. This allows data removal from the IPQ with a minimum of handling and without the necessity of a physical contact. The Intelligent Paper™ radio frequency transceiver is a two-way digital transceiver built from a single microchip. It has functions incorporated to provide for data exchange interoperability and other data handling and transfer functions including secure and encrypted data transfer. The digital radio interface on the data processing system is connected to a standard RS-232 serial interface. Since data from the IPQ is electronic, it is immediately available for processing and does not require the massive infrastructure required by paper and imaging based systems.

The paper design of the device facilitates rough handling such as might be expected by mail delivery and respondent abuse. The design and construction of the IPQ are in all respects satisfactory for its intended single use purpose.

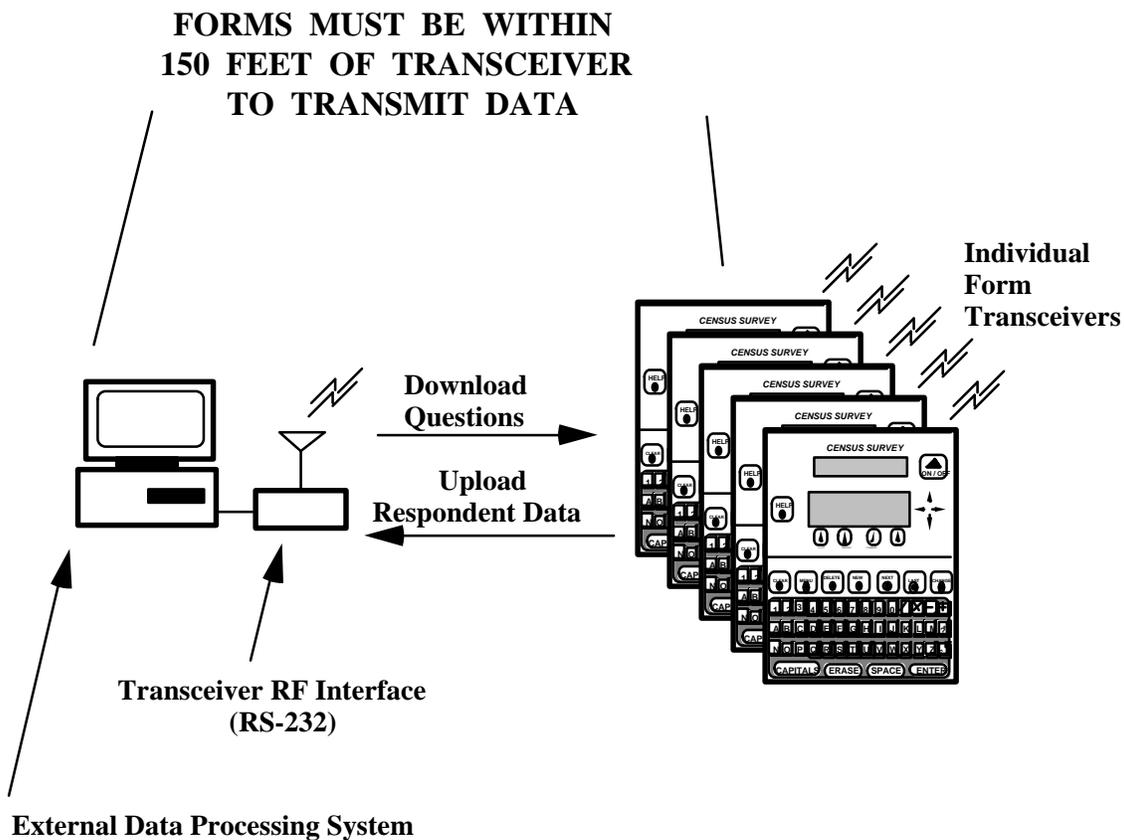


Figure 3 • Intelligent Paper™ to Data Processing System RF Interface

THE INTELLIGENT PAPER QUESTIONNAIRE

The Intelligent Paper™ Questionnaire (IPQ) design shown in Figure 1 is a general purpose design intended for United States Bureau of the Census use. The use of the IPQ will improve the data collection process and reduce the costs associated with the census data collection and capture effort. A benefit of the IPQ is the ability to maintain census question quantity, content, and improve the quality of the data collected.

The basic topography and appearance of the IPQ are simple, intended for use by a variety of persons, and may include different languages.

For census data collection, the IPQ offers many benefits including the ease of use by the respondent. It is simple and straight forward with each question presented on the LCD with the respondent's answer simply typed in or selected by a softswitch choice. This eliminates the input of handwritten data into the capture system and its associated processing. Use of software controlled softswitches further improves the ability of the device to instruct the user in inputting the desired data and facilitates a "walk through" approach to respondent data entry. Figure 3 illustrates an example of a question posed to the respondent and the answer set presented on the LCD. The answer set corresponds to the softswitches.

The IPQ provides the survey designer much flexibility in the designing of questions. The IPQ provides the ability to use branch questions, i.e. the question presentation sequence to the respondent is determined on the basis of the respondent's answers to earlier questions. Hence, "the length" of the survey is tailored to each respondent while in use. The IPQ, in effect, provides the ability to place into the hands of every respondent a fully functional, electronic data collection "Kiosk" or computer assisted self interview (CASI) device.

Benefits of the IPQ accrue as the result of savings in both capital costs and time. The IPQ eliminates the data capture and preprocessing steps. Data is directly collected by the data processing system via the two-way digital radio link from the IPQ. This requires only a low cost, digital transceiver interfaced with the data processing system. As a radio function, the IPQ only has to be in the proximity of the data capture radio. This eliminates the need for most mechanical paper handling systems, since it is not necessary to open the envelope to collect the IPQ's data. Infrastructure components eliminated by the IPQ include the physical handling machinery, the imaging system and its associated Optical Character Recognition (OCR) and Intelligent Character Recognition (ICR) data processes. Since the data received through the IPQ is already in digital format, all preprocessing and manual data input and OCR/ICR correction functions are eliminated. The time saved by eliminating the imaging preprocessing functions alone would justify use of the IPQ.

THE US CENSUS INTELLIGENT PAPER QUESTIONNAIRE PROGRAM

The United States Census Bureau is planning to undertake an adaptation program to evaluate specific configurations and test the IPQ on one or more of its on-going surveys. The program will have two phases. The objective of the first phase is to define and develop the IPQ topology and "buttonology". As shown by the topology presented in Figure 1, a common general purpose topology that will allow the IPQ to be used for several census applications is desired. However, specific topologies may be developed for other specific surveys. An additional research area of the first phase is an infrastructure analysis. The purpose of this analysis is to determine the processing requirements necessary to most effectively utilize the IPQ. This includes such questions as, "Where is the data to be transferred to an external data processing system?" Radio readers could be installed anywhere including the post office. The data transferred through the radio system at the post office would then be transferred electronically to the Census Bureau. The IPQs could be disposed of directly from the post office eliminating the need for postal delivery of the IPQs to the Census Bureau. Handling and storage at the Census Bureau are eliminated.

INTELLIGENT PAPER QUESTIONNAIRE CENSUS USES

Several potential IPQ uses have been identified by the US Census Bureau. It appears that the IPQ could have practical value for their evolving Continuous Measurement System (CMS), expected to survey 500,000 households per month continuously, and other on-going surveys conducted by the Census Bureau for other United States Government agencies. The IPQ could potentially replace laptop personal computers for in-person computer assisted interviews. It is possible to build a robust IPQ that can incorporate the power of a 100 MHz, 486 processor. A Pentium based processor will be available in early 1997. Such a design, considered a limited use product as opposed

to single use, disposable product, could have great utility and will cost only 10-20% that of a similarly configured laptop.

A feature of the general purpose IPQ that makes its prospective use in other surveys possible is the ease in which the questionnaire is changed through its software. Questions may be downloaded via the radio link into the IPQ at any time. Therefore, changes can be made to the IPQ just prior to mailing. This feature saves the lead time required for printed forms and, in the case of the CMS program, would allow changes to the questionnaire that might evolve as experience is gained through a continuous survey program.

The light weight and cost of the general purpose IPQ make it a prime candidate for use in conducting non-response-follow-up (NRFU) interviews, and in particular, where the survey will include a comparison of information previously received from a respondent. In this case, the data and questions would be inputted at a Census field office using a personal computer and a radio interface. Loss or destruction of the IPQ within the NRFU environment is cost tolerable as opposed to other methods such as laptop PC use.

PAPER AND PENCIL (PP) QUESTIONNAIRE VERSUS THE PROPOSED INTELLIGENT PAPER™ (IP) QUESTIONNAIRE COMPARISON

QUESTIONNAIRE LENGTH	Seeing entire length is intimidating.	LCD Display shows one question at a time.
BRANCH QUESTIONS	<ul style="list-style-type: none"> • All questions are printed. • Respondent must determine and follow instructions. 	<ul style="list-style-type: none"> • Question sequence programmed into microcontroller.
FOREIGN LANGUAGES	<ul style="list-style-type: none"> • Separate form for each language. • Who to send to? 	<ul style="list-style-type: none"> • Multiple languages on same IP Questionnaire is possible.
SURVEY CONTENT & FORMAT OF QUESTIONS -ADAPTABILITY	<ul style="list-style-type: none"> • Survey content and question design done well in advance. • Layout and Printing completed result in no last minute changes. 	<ul style="list-style-type: none"> • Questions are in software. Content and form may be changed up until the time of mailing. • Questions changed electronically through the RF transceiver.
RESPONDENT'S DATA ENTRY -ACCURACY	<ul style="list-style-type: none"> • No way to quality control answers. • Required post processing. 	<ul style="list-style-type: none"> • Software guides respondent. • Software "edit" checks responses. • Less post processing time, if any.
DATA CAPTURE & POST PROCESSING	<ul style="list-style-type: none"> • Labor & Equipment Intensive • Form must be handled mechanically. • Use of scanner and OCR/ICR techniques. - Clerk must interpret nonreadable answers or handwritten data. - Manual transcription errors. • Requires specialized processing equipment. 	<ul style="list-style-type: none"> • Required time to read data from transceiver - less than 0.3 seconds. Data ready to process. • Responses stored in memory already in digital form. • Survey device must be moved within range of receiving computer's digital transceiver - less than 50 feet. No need to open envelope. • Processing equipment is a digital transceiver the size of a cigar box sitting next to a computer.

DISPOSITION OF FORMS	<ul style="list-style-type: none"> • After scanned, digitized and edited can be destroyed. 	<ul style="list-style-type: none"> • After post processing, in case of failure of the post processing system, may be destroyed. • Shelf life approx. 3 years.
PRIVACY SAFEGUARD	<ul style="list-style-type: none"> • Responses can be read and copied easily. 	<ul style="list-style-type: none"> • Responses can be read after they are entered into the post processing system.
SECURITY SAFEGUARD	<ul style="list-style-type: none"> • Dependent on form handling and disposition procedures. 	<ul style="list-style-type: none"> • Responses read only by personnel who have encryption codes to transfer the data into the post processing system.
TECHNOLOGY RELIABILITY	<ul style="list-style-type: none"> • Known or calculated based on past experience and testing. 	<ul style="list-style-type: none"> • Unknown since no actual field test has been conducted. • However, all components used in other common applications.
TOPOLOGY FOR EASE OF RESPONDENT'S USE	<ul style="list-style-type: none"> • Extensively tested. • Some measure of uncertainty • Poor mail back rates to test long forms during 1990. 	<ul style="list-style-type: none"> • Look of real form unknown. • Mail-back rate unknown. • Sophisticated form that may be intimidating to some respondents. • Tradeoffs - Unknown
REPLACEMENT FORMS	<ul style="list-style-type: none"> • Duplicate short paper forms not too big of a problem. 	<ul style="list-style-type: none"> • Additional unused IP forms may be expensive.
COST	<ul style="list-style-type: none"> • Paper printing cost are known. • Cost of processing is significant. 	<ul style="list-style-type: none"> • Higher cost of the IP form is offset by reduced post processing costs. This merits further evaluation of IP form alternative. • Cost estimates based on development and testing are not yet available.
PROMOTION and MARKETING	<ul style="list-style-type: none"> • Bulky, old fashion. 	<ul style="list-style-type: none"> • Compact in size; "smart" form; technologically innovative.
TIMELINESS	<ul style="list-style-type: none"> • Time to manually open, scan, OCR/ICR process, edit check, and manually enter corrections. 	<ul style="list-style-type: none"> • Time to read data from transceiver - less than a second. Data ready to process.

Other government uses of the Intelligent Paper™ technology include tax collection and filing, general application forms, and other large scale data collection projects. If adopted, the use of IPQ as a tax form by the United States Internal Revenue Service will achieve a long sought after goal of fully automating the tax filing process.

SUMMARY

The Intelligent Paper™ Questionnaire technology holds many potential benefits for users performing large scale data collection efforts. Its cost and time savings possibilities are significant. The IPQ is a tool that affords survey organizations unlimited possibilities of survey content, question presentation and construction that are far and above any potential pencil and paper processes. All of these factors unite within the IPQ technology to afford this new electronic solution to data collection.

AUTHORS

Michel Lettre is the Assistant Director for the Maryland Office of Planning. The Planning Office houses the Maryland State Data Center which provides access to and dissemination of census and related data sets through a cooperative agreement with the U.S. Bureau of the Census. Mr. Lettre is also responsible for Geographic Information Systems in support of planning for the overall growth and development of the State.

Mr. Lettre served as the State Census Coordinator for the Governor's 1990 Census Promotion Campaign and as principal staff to the Governor's 1991 Redistricting Advisory Committee.

Mr. Lettre was a member from 1992 to 1994 of the National Academy of Sciences, National Research Council Panel on Census Requirements in the Year 2000 and Beyond. He currently serves on the followup Panel on Alternative Census Methodologies.

Mr. Lettre has a Master of Science in public administration and a Bachelor of Science in business administration, both from Carnegie-Mellon University.

Jim P. Willard is the Chairman of Votation Corporation and has been responsible for the development of the Intelligent Paper™ technology. He has also directed the development of the company's public voting systems which incorporate an Intelligent Paper™ product configured as an electronic Mail-In Ballot.

Prior to establishing Votation Corporation, Mr. Willard was the President and Chief Executive Officer of Engineering Sciences Corporation, a software development company specializing in the design and development of large scale realtime data collection systems. Mr. Willard has over twenty years experience in the design and development of large scale data processing systems for industry and government uses. Mr. Willard is the inventor and patent holder of Intelligent Paper.

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